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Impact of Predation by *Ostracion immaculatus* (Pisces: Ostraciidae) on the Macrofouling Community Structure in Kanayama Bay, Kii Peninsula (Japan)

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Abstract An Investigation on the impact of predation by *Ostracion immaculatus* on fouling community structure in Kanayama Bay, Kii Peninsula, Japan was undertaken from April 1994 to February 1995. Caging experiments with three size groups of *O. immaculatus* using predator inclusion as well as exclusion treatment confirmed that predation by this fish had significant impact on the structure of fouling community. The importance of predation was manifested mainly through the influence of fish on ascidians, with fish exclusion resulting in their monopolization of the substratum within six months of exposure of the panels. The competitive exclusion of bryozoans and barnacles was observed in the absence of predators. Solitary and competitively inferior colonial forms survived better in the presence of predators. Predation by *O. immaculatus* was compared with the natural predation by exposing test panels outside the cage.

Key words: Macrofouling; Community structure; Caging experiments; Predation; *Ostracion immaculatus*; Kanayama Bay; Japan

Introduction

Predation has often been considered a major force structuring the intertidal and sub tidal sessile invertebrate communities (Lewontin, 1969; Sutherland, 1974b; Paine, 1974; Connell, 1975; Connell & Slatyer, 1977) where space is at premium (Connell, 1961; Dayton, 1971; Paine, 1974). Predators ranging from molluscs to fishes feed on sessile biota and create free space by preventing single species monopolization (Paine, 1966; Lubchenco & Menge, 1978). In natural populations with large number of species, it becomes a formidable task to pinpoint the role played by individual species towards total community structure (Paine, 1974).

It is a well-known fact that feeding by fishes has considerable impact on the distribution and abundance of seaweeds and benthic invertebrates in tropical reef communities (Wellington, 1982; Lewis, 1986; Horn, 1989; Littler *et al.*, 1989; Hay, 1991). Fish predation on settling larvae also plays a part in determining adult distributions (Gaines & Roughgarden, 1987; Olson & McPherson, 1987). Sutherland (1974a,b), Sutherland & Karlson (1977); Foster (1975); Day (1977); Mook (1977); Russ (1980)); Smedes & Hurd (1981) have highlighted the importance of fish predation on macrofouling community structure by employing caging experiments. The present investigation intends to elucidate the importance of predation by *O. immaculatus* Temminck et. Schlegel 1850, a trunkfish, in structuring macrofouling community in Kanayama Bay.

Ostracion immaculatus is omnivorous and is widely distributed in the coastal waters of Japan from Northern Honshu to Shikoku (Nakabo, 1993). They feed on ascidians quite intensively and preferentially with ascidians being invariably present in the gut content of fishes collected from various localities around Kii peninsula, Japan (Raveendran & Harada, 1996).

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Materials and methods

Site description

The study was undertaken in the semi-enclosed Kanayama Bay located on the Pacific coast of Japan (33°41'N; 135°21' E). This Bay is protected by break water systems from heavy swells and waves because it is used for anchoring rafts with cages for culturing fishes. The maximum depth near the raft is ~2.5 m during the lowest low tide.

Experimental design

A cage made of nylon rope (2 mm diameter, mesh size 1.5 cm², diagonal 2.5 cm) was partitioned into four equal compartments (Fig. 1). Each compartment, measuring 1.9 x 0.95 x 2.4 m, provided ample space for free movement of the fishes. Bamboo poles with lead weights were attached to the bottom of the four sides of the net to maintain a rectangular shape after deployment.

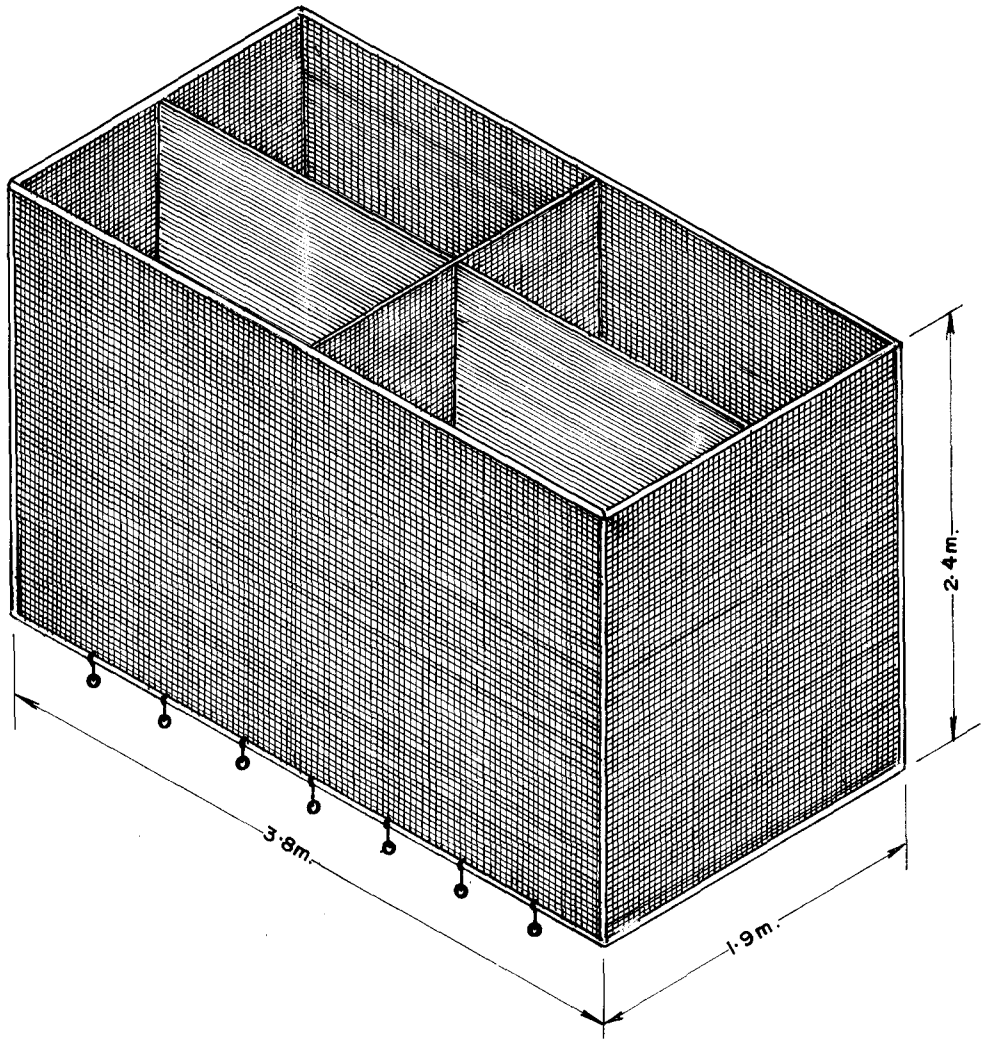

Fig. 1. Cage used in predation experiment.

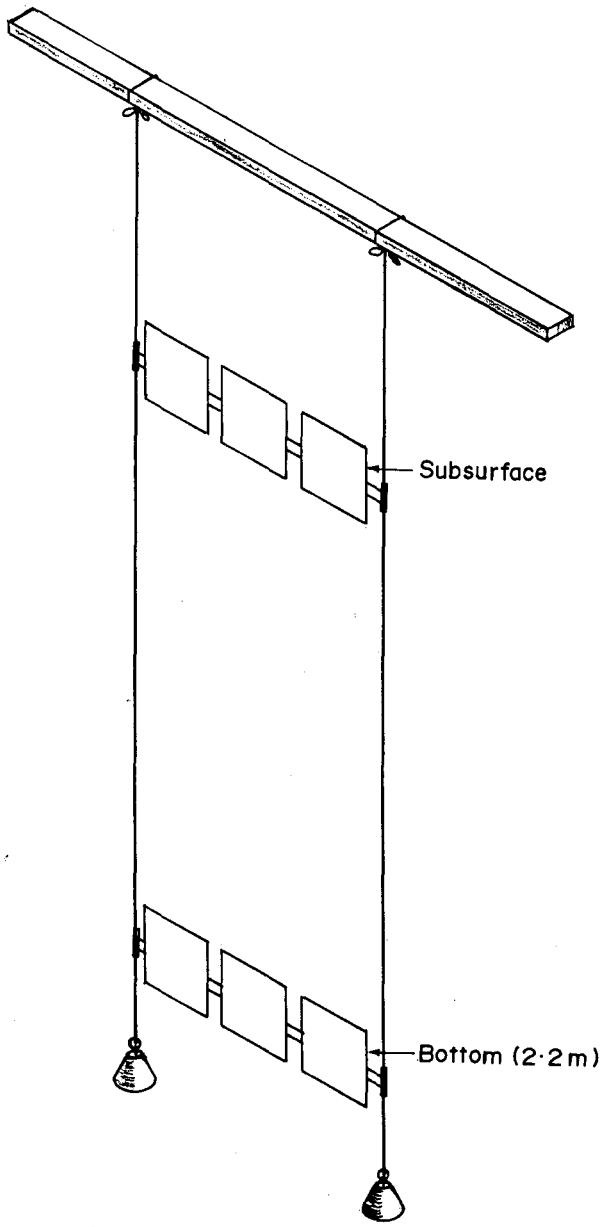

Fig. 2. Design of panel assembly.

The net was knitted in such a way that the mesh remained fully open facilitating free larval entry into the cage.

A unit consisted of two Fibre Reinforced Plastic (FRP) bars, each holding four FRP panels (20 x 20 cm) and suspended at subsurface and bottom (1.2 m) depths with a pair of nylon ropes (Fig. 2). Lead weights of 2.5 kg were attached to the end of the rope to minimize the movement of the bars. One such unit was exposed in three compartments having two fishes each of large, medium and small (Table 1). Fourth compartment with only the test panels served as control. An additional unit was also exposed outside the cage for comparing natural predation with that of *O.*

Table 1. Initial and final length and wet weight of fishes used in the experiment.

Fish Size	N	Initial		Final	
		Length (cm)	Wet wt. (g)	Length (cm)	Wet wt. (g)
Large	2	18±1.0	200±5.0	20±0.4	273±62
Medium	2	12±2.0	75±2.0	13±0.6	88±8
Small	2	9±0.2	52±1.0	11±0.3	74±4

immaculatus. Since these fishes were observed to feed on panels exposed at subsurface and bottom, it was decided to clarify any depth-wise variation in feeding impact. The selected fish density was based on our experience in the field wherein often one or two fishes encountered in the vicinity of fouling panel assembly. Since fishes of different size groups were observed in the field, it was decided to test the size group effect. All the experimental units were oriented to the same direction throughout the study period. The panels at the bottom were kept sufficiently above the mud level to minimize silting and also to avoid predation by other benthic predators.

Sampling and observations

The experiment was carried out from April 1994 to February 1995. Panels were examined once every month. On retrieval, they were transported to the laboratory in a large tank containing seawater and were kept immersed in running seawater until returned to the field. The percentage cover of major fouling organisms occupying the central 15 x 15 cm area of the panels was recorded using a 10 x 10 grid of 225 cm^2 area so that each grid represents 1% cover. Peripheral area of 2.5 cm was excluded to avoid edge effect and possible handling damages. After careful handling and adopting non-destructive means of analysis, the panels were returned to the field within 2-3 days. Biomass of dominant fouling organisms (on wet weight basis) was taken only during the last observation.

Data analysis

Mean percentage cover of major fouling organisms from triplicate panels during 1 to 9 months exposure period was subjected to analysis of variance (ANOVA) to find out any significant effect of fish size on fouling community structure. The data from three cages containing different size groups of fishes were treated collectively and ANOVA was conducted for understanding the impact of fishes as well as depth of exposure on the fouling community.

Results

All the fishes used for caging experiments were healthy even at the time of winding up the experiment. All of them showed increase in length as well as their wet weight (Table 1). The number of species as well as mean percentage cover of major fouling organisms revealed no significant variation among large, medium and small groups of fishes ($p>0.05$).

Number of species

The colonization curve showed an increasing trend with increasing period of exposure on all the experimental panels subjected to predation by fish, exposed at subsurface depth. On the contrary, a reverse trend was observed on the control panels (Fig. 3). On natural panels exposed outside the cage, there was an initial decrease in the number of species with increasing exposure period. However, after five months, there was a marginal recovery with the number of species corresponding more or less to that of experimental panels. Almost a similar trend was observed on

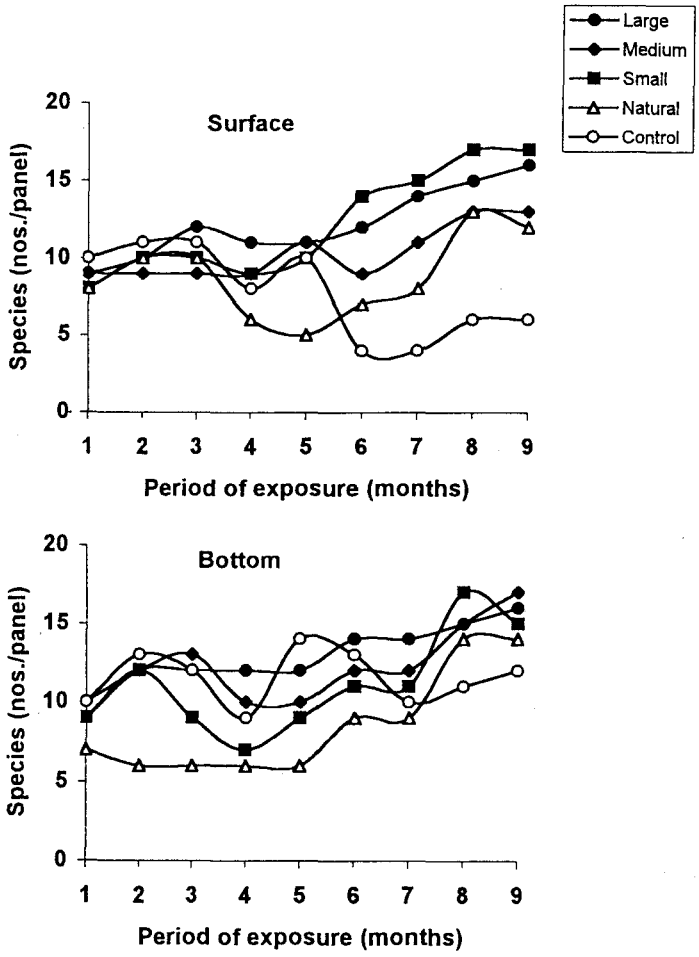

Fig. 3. Colonization curve on FRP panels immersed for 9 months in Kanayama Bay.

the bottom experimental and natural panels. Control panels showed a fluctuating trend with minimum number of species being recorded towards the end of the experiment.

Significant variation was observed in the number of species between experimental and control at subsurface and experimental and natural panels at both the depths ($p<0.05$). Significant depth-wise variation was observed only in the case of control panels ($p<0.05$) with greater species present on bottom panels.

Biomass and Percentage cover

The biomass and percentage cover of major fouling organisms, which tend to characterize the community, are described below.

Ascidians

Drastic differences were observed in ascidian biomass between experimental and control as well as between natural and control. They contributed substantially to the biomass on control panels (Fig. 4).

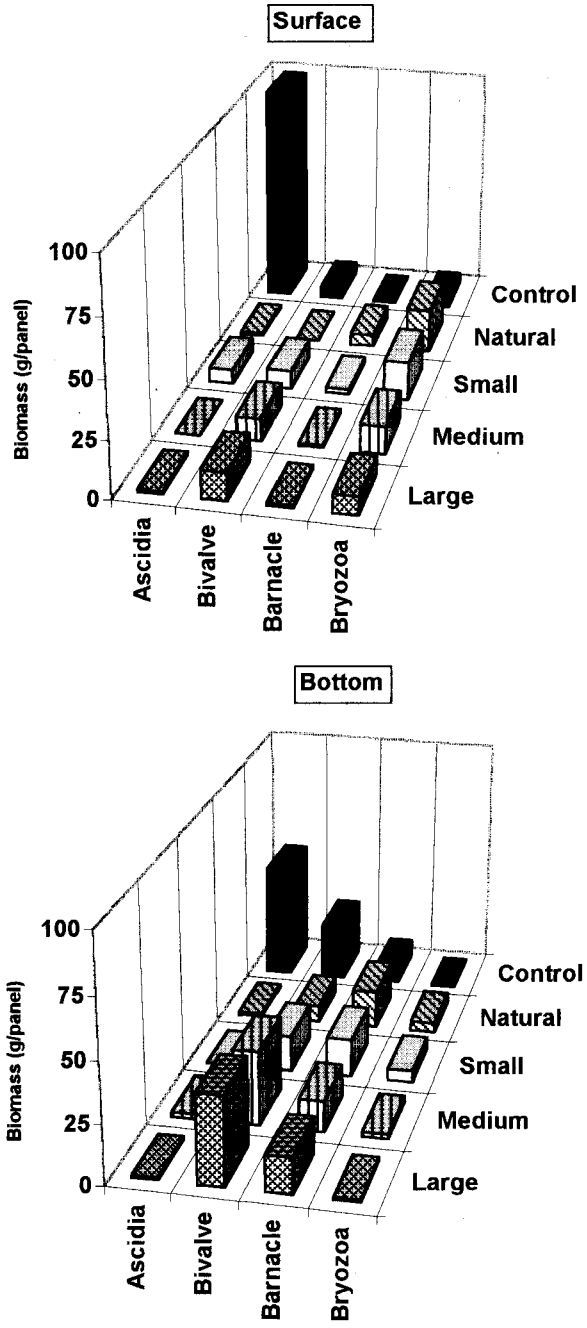

Fig. 4. Biomass of dominant fouling organisms on FRP panels immersed for 9 months in Kanayama Bay.

Ascidians formed the major space occupier on all control panels unlike their experimental and natural counterparts (Fig. 5). Therefore, significant difference in ascidian coverage was noticed between experimental as well as natural panels with that of the control ($p<0.05$). The insignificant variation in ascidian cover observed between experimental and natural panel is noticeable ($p>$

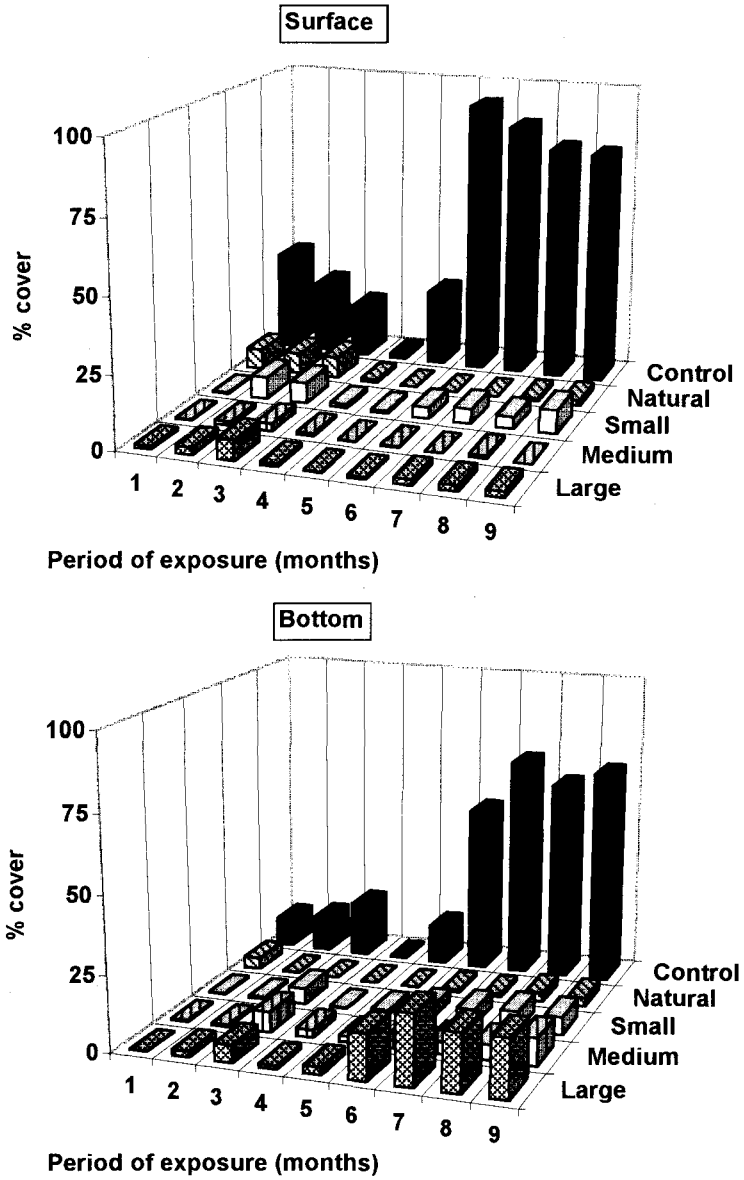

Fig. 5. Percentage cover of ascidians on FRP panels immersed for 9 months in Kanayama Bay.

0.05). No significant depth wise variation in ascidian cover was noticed in any of the treatments ($p>0.05$).

Bivalves

The bivalve biomass was greater on experimental and control panels than on natural ones at both the depths (Fig. 4). Greater biomass was recorded at bottom compared to subsurface.

Percentage cover was more on experimental panels than on control and natural ones (Fig. 6). Significant differences were observed between experimental and control as well as natural panels exposed at subsurface depth ($p<0.05$), but no such difference was evident at bottom ($p>0.05$). No

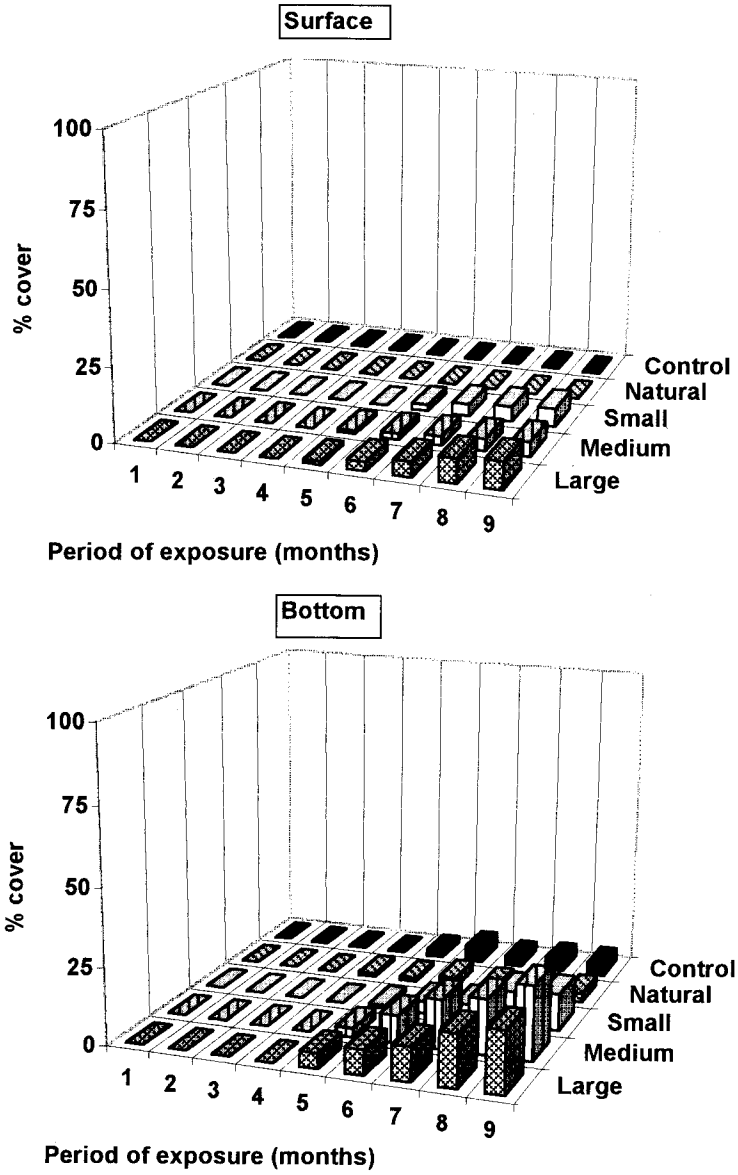

Fig. 6. Percentage cover of bivalves on FRP panels immersed for 9 months in Kanayama Bay.

significant difference was observed between natural and control panels at both the depths ($p>0.05$). Significant depth-wise variation in coverage was observed in the case of control as well as natural panels ($p<0.05$) with greater coverage observed on bottom panels. No such difference was discernible on experimental panels ($p>0.05$).

Barnacles

In general, greater biomass values were recorded on bottom panels. Although, no noticeable difference in biomass was observed between any of the treatments at subsurface depth, greater biomass values were recorded on experimental and natural panels than on control at bottom (Fig.

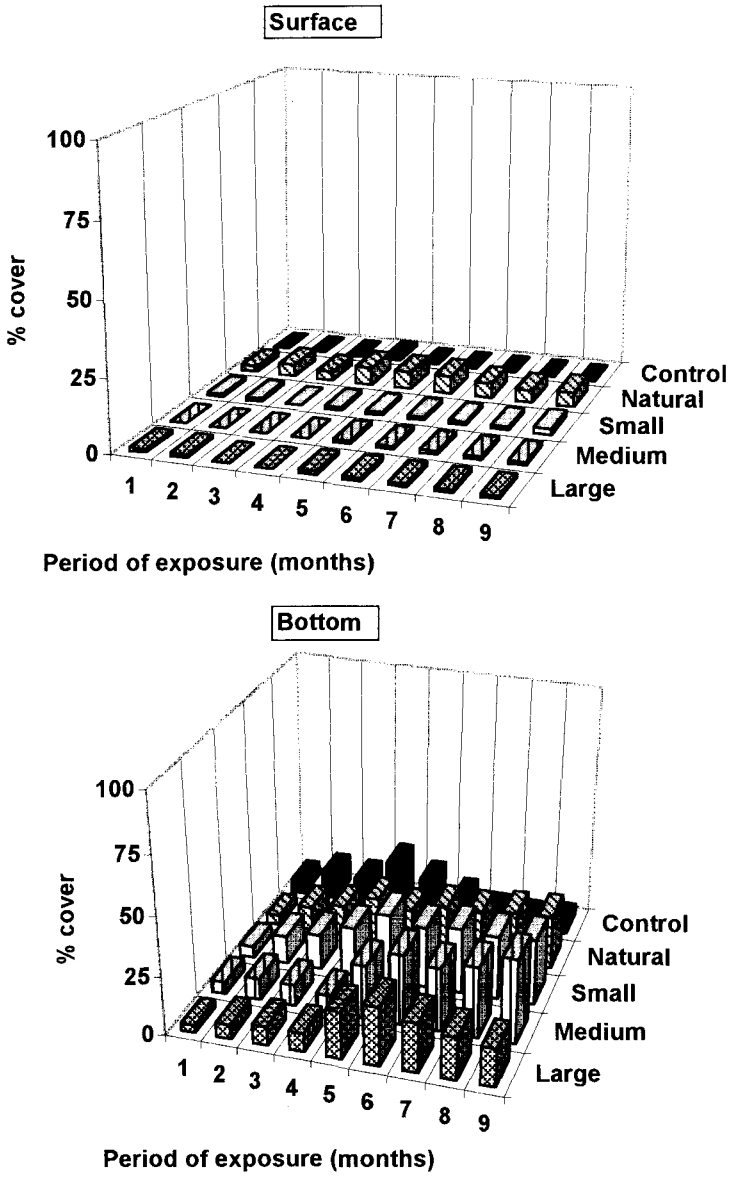

Fig. 7. Percentage cover of barnacles on FRP panels immersed for 9 months in Kanayama Bay.

4).

Barnacle cover exhibited significant variation between experimental and control as well as control and natural panels at both depths and between experimental and natural panels at subsurface depth ($p<0.05$). An exception was experimental vs natural at bottom ($p>0.05$). Irrespective of the treatments, all the panels exhibited significantly greater coverage at bottom than their subsurface counterparts ($p<0.001$).

Bryozoans

Experimental and natural panels had greater biomass compared to control at both the depths

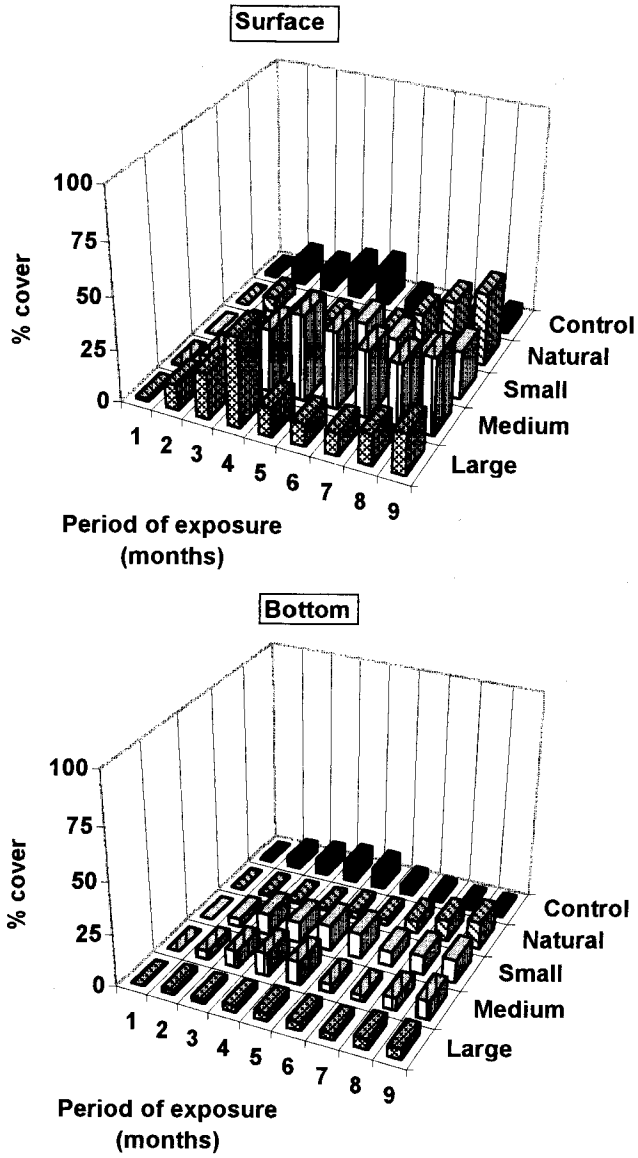

Fig. 8. Percentage cover of bryozoa on FRP panels immersed for 9 months in Kanayama Bay.

of panel exposure (Fig. 4). Greater biomass was observed at subsurface.

In general, poor bryozoan cover was observed on control panels (Fig. 8). The difference in coverage was more pronounced at subsurface depth where greater bryozoan coverage was generally observed. Significant variation in bryozoan cover was observed only in the case of experimental vs control panels at subsurface depth ($p<0.05$). Bryozoan cover showed significant depth-wise variation in the case of experimental panels ($p<0.05$). However, no such trend was evident in the case of control as well as natural panels ($p>0.05$).

Discussion

The calm shallow waters of Kanayama Bay provided conductive environment for active predation by *Ostracion immaculatus*. The importance of this fish to the community structure was manifested mainly through its influence on ascidians. Colonial ascidians are superior space competitors. They grew abundantly on both exposed and protected sides of the panels under predation free conditions. For example, control panels immersed for more than six months from April to September were completely co-dominated by two species of ascidians, namely *Didemnum moseleyi* and *Polyclinum constellatum*. Being a dominant competitor, it was capable of rapidly excluding other species such as bryozoans, bivalves and barnacles from the primary substratum by over growth competition. At the same time, predation by *O. immaculatus* led to better survival of competitively inferior colonial/solitary forms on experimental panels. For example, the greater survival of colonial bryozoan, *Watersipora subtorquata* at subsurface and barnacle, *Balanus trigonus* at bottom was observed. Thus, in the present system, competition does occur, but the community is structured primarily by predation.

Poor biomass and coverage of ascidians on natural panels clearly indicates the intensive natural predation on them in Kanayama Bay. That is why ascidians, in this bay, are not normally seen on fully exposed surface of rafts and other coastal structures (personal observation, TVR). However, our data shows that ascidians such as *P. constellatum* and *D. moseleyi* grow profusely on the lighted side of the panels (Fig. 3) when afforded protection from predators. Olson (1983) has also reported the common occurrence of Didemnidae in the fully sunlit areas of the tropical coral reefs. However, the general belief is that the ascidians survive better in cryptic/shaded environments (Jackson, 1977; Tursi and Mataresse, 1981; Nandakumar, 1995). The photonegative response of ascidian tadpoles prior to settlement has often been cited as the reason why ascidians are generally absent/poorly represented on the exposed/lighted surface. On the contrary, we believe that the reported dominance of this species on the shaded side may be because visual predators like fish are less active in feeding on the shaded side compared to the lighted side of the panels. The low density of certain epifaunal ascidians in the rocky subtidal zone of the San Juan Islands has been attributed to predation (Young, 1985).

Present study supports the theory of community structure that has been developed for the rocky intertidal system (Paine, 1966; Dayton, 1971; Connell, 1975). This theory asserts that a keystone predator can increase both species diversity and overall density within a community by preying on the competitive dominant within the system. In this manner the keystone predator prevents resource monopolization by one or a few species in the community. Selective predation on ascidians by *O. immaculatus* led to increased species diversity on experimental panels by preventing monopolization of space as reported by Day (1977) and Paine (1966; 1976). At the same time, gradual monopolization of the substratum by ascidians led to poor species diversity on control panels. The fewer number of species on natural panels was probably due to non-selective predation.

In many of the caging experiments, intended to elucidate the role of predation on macrofouling community, ascidians dominated on the caged panels (see Table 3, Schmidt and Warner, 1984). The greater survival of ascidians on caged panels than the uncaged ones has been attributed to the avoidance of predation by fishes (Sutherland, 1974; Sutherland and Karlson, 1977; Russ, 1980). However, the validity of these experiments was questioned because of the impact that cages themselves have on the community (Schmidt and Warner, 1984; Stocker, 1986). Artefacts such as alteration of hydrodynamics and fouling of meshes might have influenced the results (Henry and Jenkins, 1995). In the present investigation we could overcome the cage effects by the use of predator inclusions for comparison with the predator exclusion so that any artefacts present would be constant across treatments. Also, the cage was cleaned after every three months to enhance the free supply of larvae of fouling organisms on test panels inside the cage.

In summary, the fouling community in Kanayama Bay is primarily structured by predator-prey

interactions with *O. immaculatus* playing an important role in predation.

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